Patent claims

1. Illumination system for a microlithography projection exposure system for illuminating an illumination field with the light from a primary light source, comprising:
   an optical axis (12, 112, 212, 312) and
   a light distribution device (25, 125, 225, 325) for receiving light from the primary light source (11, 111, 211, 311) and for producing a two-dimensional intensity distribution (35) which can be set variably in a pupil-shaping surface (31, 131, 231, 331) of the illumination system,
   wherein the light distribution device has at least one optical modulation device (20, 120, 220, 320, 420) for controllable changing of the angular distribution of the light incident on the optical modulation device.

2. Illumination system according to Claim 1, wherein the optical modulation device (20, 120, 220, 320, 420) has an array of individual elements (21, 121, 221, 321, 421) that can be driven individually to change the angle of the radiation incident on the individual elements.

3. Illumination system according to Claim 1 or 2, wherein the optical modulation device is constructed and can be controlled in such a way that substantially all of the light intensity that is incident on the optical modulation device is deflected into a usable region of the pupil-shaping surface (31, 131, 231, 331).

4. Illumination system according to one of the preceding claims, wherein, between the optical modulation device (20, 120, 220, 320) and the pupil-shaping surface (31, 231, 331), an optical

system (30, 230, 330) is provided to convert the angular distribution produced by the optical modulation device into a spatial distribution in the pupil-shaping surface (31, 231, 331).

5. Illumination system according to Claim 4, wherein the optical system (30, 231) has a focal length which can be set variably and which can preferably be set continuously.

6. Illumination system according to one of the preceding claims, wherein an axicon system is arranged between the optical modulation device (20, 220) and the pupil-shaping surface (31, 231).

7. Illumination system according to one of Claims 1 to 3, wherein a space between the optical modulation device (120) and the pupil-shaping surface (131) is free of optical components.

8. Illumination system according to Claim 7, wherein a distance between the optical modulation device (120) and the pupil-shaping surface (131) is so great that the pupil-shaping surface (131) lies in the far-field region of the optical modulation device (121).

9. Illumination system according to one of the preceding claims, wherein the optical modulation device is a reflective optical modulation device (20, 120, 220, 320, 420), which preferably is arranged obliquely with respect to the optical axis (12, 112, 212, 312) in the manner of a deflection mirror.

10. Illumination system according to one of the preceding claims, wherein, between the optical modulation device (20, 120, 220) and the pupil-shaping surface (31, 131, 231) there is an optical

distance which is selected such that the angles between the optical axis (12, 112, 212) and light beams belonging to the angular distribution in the region of the pupil-shaping surface (31, 131, 231) are less than about 5°, in particular less than about 3°.

11. Illumination system according to one of the preceding claims, wherein the optical modulation device has at least one mirror arrangement (20, 120, 320, 420) having an array of individual mirrors (21, 121, 321, 421) that can be controlled individually in order to change an angular distribution of the light incident on the mirror arrangement.

12. Illumination system according to Claim 11, wherein at least some of the individual mirrors, in particular all the individual mirrors (21), have a flat mirror surface.

13. Illumination system according to Claim 11 or 12, wherein at least some of the individual mirrors, in particular all the individual mirrors, are formed as curved mirrors with a finite mirror focal length, the mirror focal length preferably being dimensioned such that the radiation incident on the individual mirrors strikes the pupil-shaping surface in substantially focused form.

14. Illumination system according to one of Claims 11 to 13, wherein the individual mirrors of the mirror arrangement (20, 120) all have the same shape and size.

15. Illumination system according to one of Claims 11 to 13, wherein the individual mirrors comprise a first mirror group and at least a second mirror group each having one or more individual mirrors,

the individual mirrors of the mirror groups having a different size and/or different shape and/or different curvature.

16. Illumination system according to one of Claims 11 to 15, wherein at least some of the individual mirrors of the mirror arrangement have an optical structure, in particular a diffractive optical structure, for forming the distribution of the radiation reflected from the individual mirror.

17. Illumination system according to one of Claims 11 to 16, wherein individual mirrors of the mirror arrangement (20, 120, 320, 420) can be tilted relative to other individual mirrors of the mirror arrangement, preferably about two tilt axes running transversely with respect to each other.

18. Illumination system according to one of Claims 1 to 10, wherein the optical modulation device (220) is an electro-optical element (220) having an array of individual elements (221), which are formed as controllable diffraction gratings and/or as acousto-optical elements.

19. Illumination system according to one of Claims 2 to 18, wherein, between the light source and the optical modulation device, there is arranged an optical device (15, 215, 315) for concentrating radiation incident on the optical device onto the individual elements (21, 221, 321, 421) of the optical modulation device (20, 220, 320, 420).

20. Illumination system according to Claim 19, wherein the optical device (15, 215) includes a two-dimensional array having telescope lens systems (16).

21. Illumination system according to claim 19, wherein the optical device includes a diffractive optical array generator (315) for transforming an incoming beam into a plurality of light beams concentrated on individual optical elements of the optical modulation device.

22. Illumination system according to claim 21, wherein the diffractive optical array generator (315) is designed as a Dammann grid.

23. Illumination system according to one of the preceding claims, wherein, between the pupil-shaping surface (31) and a plane (65) of the illumination field, there is arranged a light mixing device (45, 380) for mixing the light of the intensity distribution.

24. Illumination system according to Claim 23, wherein the light mixing device comprises at least one integrator rod (45) having an entry surface (44), and the pupil-shaping surface (31) preferably lies in the region of a plane which is located upstream of the entry surface and which is a Fourier-transformed plane in relation to the entry surface.

25. Illumination system according to Claim 23, wherein the light mixing device comprises at least one fly's eye condenser (380) having an entry surface, and the pupil-shaping surface preferably lies in the region of the entry surface or a surface which is optically conjugate with respect to the entry surface.

26. Illumination system according to Claim 25, characterized by controlling the optical modulation device in such a way that individual radiation channels of the fly's eye condenser

(380) are either substantially completely irradiated or substantially completely non-irradiated.

27. Illumination system according to Claim 25 or 26, wherein the light distribution device has at least one diffractive optical element (390, 490) arranged optically between the optical modulation device and the pupil-shaping surface for receiving light emerging from the optical modulation device and for modifying the light by introducing an angular distribution according to an effect function defined by the configuration of the diffractive optical element.

28. Illumination system according to Claim 27, wherein the diffractive optical element (390, 490) is desingned such that a beam emerging from an individual element of the optical modulation device is shaped by the diffractive optical element to conform to the shape and size of one single optical channel or a group of adjacent optical channels of the fly's eye condenser.

29. Illumination system according to Claim 27 or 28, wherein the diffractive optical element (390, 490) is a computer generated hologram (CGH).

30. Illumination system according to one of Claims 25 to 29, wherein the fly's eye condenser (380) is not assigned any mask for the individual blocking of radiation channels.

31. Illumination system according to one of Claims 1 to 22, wherein no fly's eye condenser nor any integrator rod is arranged between the pupil-shaping surface (231) and a plane (265) of the illumination field.

32. Illumination system according to one of the preceding claims, wherein, in or in the vicinity of the pupil-shaping surface (231), there is arranged a raster element (232) for shaping and homogenizing the intensity distribution in a following field plane (250) of the illumination system.

33. Illumination system according to one of the preceding claims, wherein, in order to drive individual elements (21, 121, 221, 321) of the optical modulation device, a control device (22, 122, 222, 322) is provided which is configured in such a way that control signals for controlling the individual elements can be varied as a function of the structure of a mask (66) to be exposed.

34. Method of producing semiconductor components and other finely structured components, having the following steps:
illuminating a reticle arranged in an object plane of a projection objective with the aid of an illumination system, which has at least one optical modulation device having a large number of individual elements that can be controlled individually in order to change the angular distribution of the radiation incident on the optical modulation device;
producing an image of the reticle on a light-sensitive substrate;
the step of illuminating the reticle comprising setting the angular distribution of the light incident on the reticle by means of the relative setting of at least two of the individual elements in relation to each other.

35. Method according to Claim 34, wherein the optical modulation device comprises a mirror arrangement

having a large number of individual mirrors that can be controlled individually, and the relative setting of the individual elements comprises tilting at least one of the individual mirrors with respect to other individual mirrors about one or more tilt axes.

36. Method according to Claim 34, in which the optical modulation device has a large number of diffraction gratings that can be controlled individually, and the relative setting comprises different changes of the diffraction effects of at least two of the diffraction gratings.

37. Method according to one of Claims 34 to 36, wherein the illumination system comprises a fly's eye condenser having a large number of radiation channels, and wherein the individual elements are controlled in such a way that radiation channels are either substantially completely illuminated or substantially completely non-illuminated.

38. Illumination system for a microlithography projection exposure installation for illuminating an illumination field with the light from a primary light source, comprising:
an optical axis (12, 112, 212) and
a light distribution device (25, 125, 225) for receiving light from the primary light source (11, 111, 211) and for producing a two-dimensional intensity distribution (35) which can be set variably in a pupil-shaping surface (31, 131, 231) of the illumination system,
wherein the light distribution device has at least one optical modulation device (20, 120, 220) for controllable changing of the angular distribution of the light incident on the optical modulation device,

wherein, between the optical modulation device (20, 120, 220) and the pupil-shaping surface (31, 231), an optical system (30, 230) is provided to convert the angular distribution produced by the optical modulation device into a spatial distribution in the pupil-shaping surface (31, 231),
wherein the optical system (30, 231) has a focal length which can be set variably.

39. Illumination system for a microlithography projection exposure installation for illuminating an illumination field with the light from a primary light source, comprising:
an optical axis (12, 112, 212) and
a light distribution device (25, 125, 225) for receiving light from the primary light source (11, 111, 211) and for producing a two-dimensional intensity distribution (35) which can be set variably in a pupil-shaping surface (31, 131, 231) of the illumination system,
wherein the light distribution device has at least one optical modulation device (20, 120, 220) for controllable changing of the angular distribution of the light incident on the optical modulation device,
wherein an axicon system is arranged between the optical modulation device (20, 220) and the pupil-shaping surface (31, 231).

40. Illumination system for a microlithography projection exposure installation for illuminating an illumination field with the light from a primary light source, comprising:
an optical axis (12, 112, 212) and
a light distribution device (25, 125, 225) for receiving light from the primary light source (11, 111, 211) and for producing a two-dimensional intensity distribution (35) which can be set

variably in a pupil-shaping surface (31, 131, 231) of the illumination system,
wherein the light distribution device has at least one optical modulation device (20, 120, 220) for controllable changing of the angular distribution of the light incident on the optical modulation device,
wherein a space between the optical modulation device (120) and the pupil-shaping surface (131) is free of optical components.

41. Illumination system for a microlithography projection exposure installation for illuminating an illumination field with the light from a primary light source, comprising:
an optical axis (12, 112, 212) and
a light distribution device (25, 125, 225) for receiving light from the primary light source (11, 111, 211) and for producing a two-dimensional intensity distribution (35) which can be set variably in a pupil-shaping surface (31, 131, 231) of the illumination system,
wherein the light distribution device has at least one optical modulation device (20, 120, 220) for controllable changing of the angular distribution of the light incident on the optical modulation device,
wherein the optical modulation device has at least one mirror arrangement (20, 120) having an array of individual mirrors (21, 121) that can be controlled individually in order to change an angular distribution of the light incident on the mirror arrangement,
wherein the individual mirrors comprise a first mirror group and at least a second mirror group each having one or more individual mirrors, the individual mirrors of the mirror groups having a different size and/or different shape and/or different curvature.

42. Illumination system for a microlithography projection exposure installation for illuminating an illumination field with the light from a primary light source, comprising:
an optical axis (12, 112, 212) and
a light distribution device (25, 125, 225) for receiving light from the primary light source (11, 111, 211) and for producing a two-dimensional intensity distribution (35) which can be set variably in a pupil-shaping surface (31, 131, 231) of the illumination system,
wherein the light distribution device has at least one optical modulation device (20, 120, 220) for controllable changing of the angular distribution of the light incident on the optical modulation device,
wherein the optical modulation device has at least one mirror arrangement (20, 120) having an array of individual mirrors (21, 121) that can be controlled individually in order to change an angular distribution of the light incident on the mirror arrangement,
wherein the individual mirrors as adaptive mirrors, in which the shape of a mirror surface can be varied.

43. Illumination system for a microlithography projection exposure installation for illuminating an illumination field with the light from a primary light source, comprising:
an optical axis (12, 112, 212) and
a light distribution device (25, 125, 225) for receiving light from the primary light source (11, 111, 211) and for producing a two-dimensional intensity distribution (35) which can be set variably in a pupil-shaping surface (31, 131, 231) of the illumination system,

wherein the light distribution device has at least one optical modulation device (20, 120, 220) for controllable changing of the angular distribution of the light incident on the optical modulation device,
wherein the optical modulation device (220) is an electro-optical element (220) having an array of individual elements (221), which are formed as controllable diffraction gratings and/or as acousto-optical elements.

44. Illumination system for a microlithography projection exposure installation for illuminating an illumination field with the light from a primary light source, comprising:
an optical axis (12, 112, 212) and
a light distribution device (25, 125, 225) for receiving light from the primary light source (11, 111, 211) and for producing a two-dimensional intensity distribution (35) which can be set variably in a pupil-shaping surface (31, 131, 231) of the illumination system,
wherein the light distribution device has at least one optical modulation device (20, 120, 220) for controllable changing of the angular distribution of the light incident on the optical modulation device,
wherein the optical modulation device (20, 120, 220, 320, 420) has an array of individual elements (21, 121, 221, 321, 421) that can be driven individually to change the angle of the radiation incident on the individual elements,
wherein, between the light source and the optical modulation device, there is arranged an optical device (15, 215, 315) for concentrating radiation incident on the optical device onto the individual elements (21, 221, 321) of the optical modulation device (20, 220, 320).

45. Illumination system according to Claim 44, wherein the optical device (15, 215) includes a two-dimensional array having telescope lens systems (16).

46. Illumination system according to claim 44, wherein the optical device includes a diffractive optical array generator (315) for transforming an incoming beam into a plurality of light beams concentrated on individual optical elements of the optical modulation device.

- - - - - - - - -